US009871580B2

(12) **United States Patent**
Fujii et al.

(10) **Patent No.: US 9,871,580 B2**
(45) **Date of Patent: Jan. 16, 2018**

(54) **TRANSMISSION APPARATUS AND NETWORK CONTROL METHOD**

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(*) Notice: Subject to any disclaimer, the term of this patent is extended or adjusted under 35 U.S.C. 154(b) by 0 days.

(21) Appl. No.: **15/095,476**

(22) Filed: **Apr. 11, 2016**

(65) **Prior Publication Data**

US 2016/0308604 A1 Oct. 20, 2016

(30) **Foreign Application Priority Data**

Apr. 20, 2015 (JP) 2015-086313

(51) **Int. Cl.**

H04B 10/038	(2013.01)
H04B 10/032	(2013.01)
H04B 10/035	(2013.01)
H04B 10/275	(2013.01)
H04J 14/02	(2006.01)

(52) **U.S. Cl.**

CPC ***H04B 10/038*** (2013.01); ***H04B 10/032*** (2013.01); ***H04B 10/035*** (2013.01); ***H04B 10/275*** (2013.01); ***H04J 14/0283*** (2013.01); ***H04J 14/0287*** (2013.01); ***H04J 14/0295*** (2013.01)

(58) **Field of Classification Search**

None

See application file for complete search history.

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(57) **ABSTRACT**

A transmission apparatus being one of a plurality of transmission apparatuses included in a ring network, including: a processor configured to: receive a specified message from a first transmission apparatus, the specified message being for setting loopback for at least one wavelength in a ring network, the specified message being transmitted when a failure of at least one optical signal having the at least one wavelength is detected in a specified link of the ring network, and set a loopback to a switch, the loopback being set for a specified wavelength of the at least one wavelength when a specified optical signal having the specified wavelength is terminated by the switch and converted to an electrical signal and when the specified optical signal having the specified wavelength is not terminated and not converted to an electrical signal by any apparatus from a second transmission apparatus to the specified link.

12 Claims, 14 Drawing Sheets

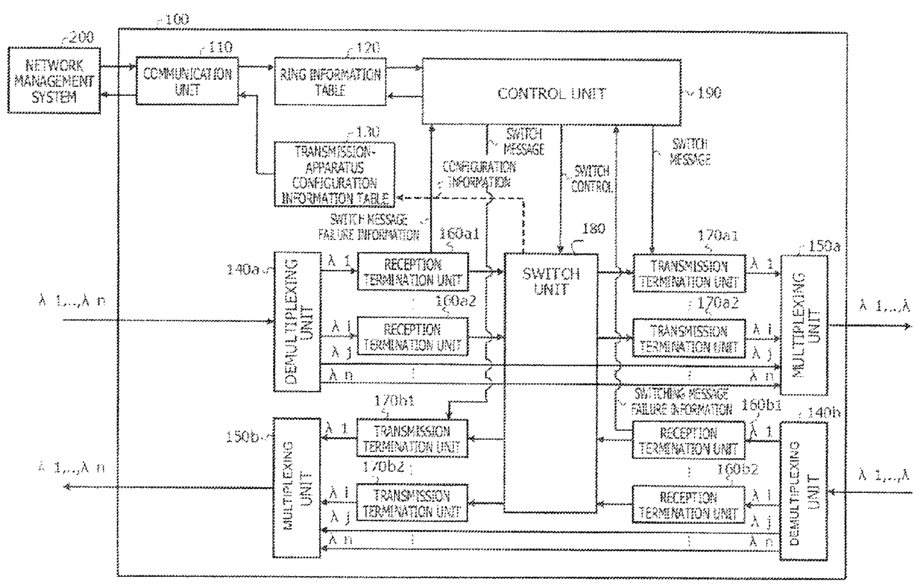


FIG. 1

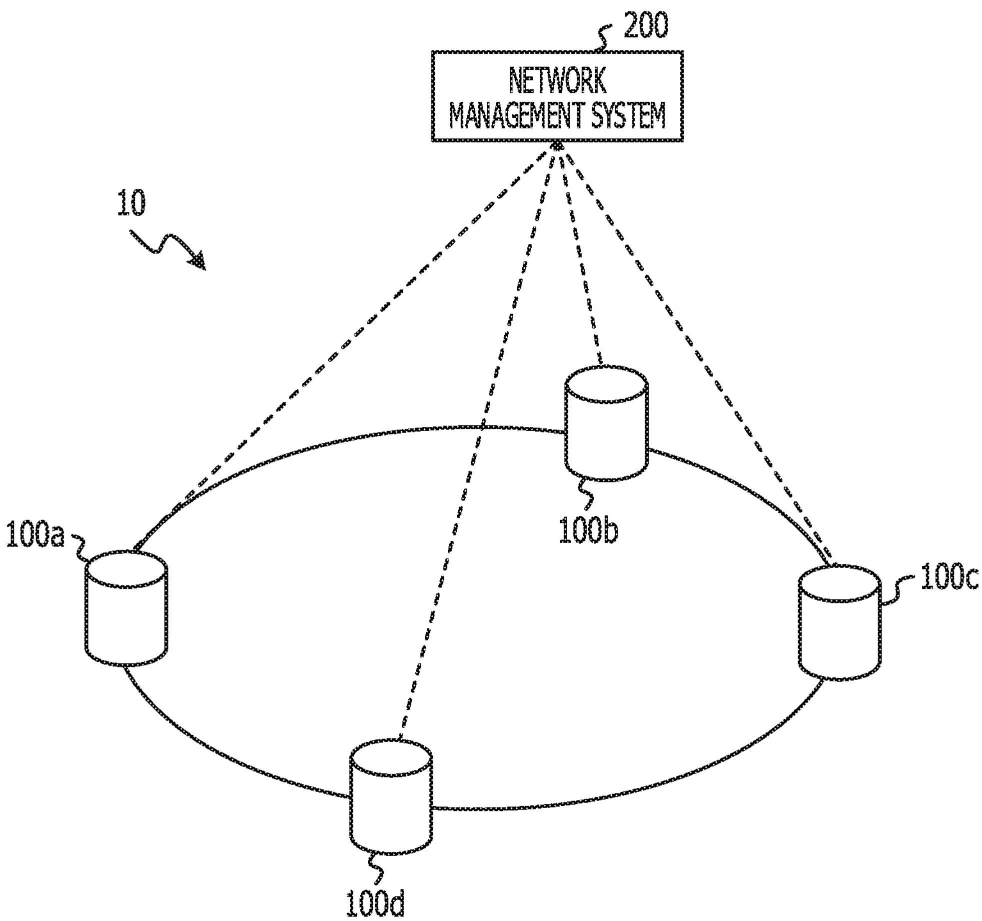
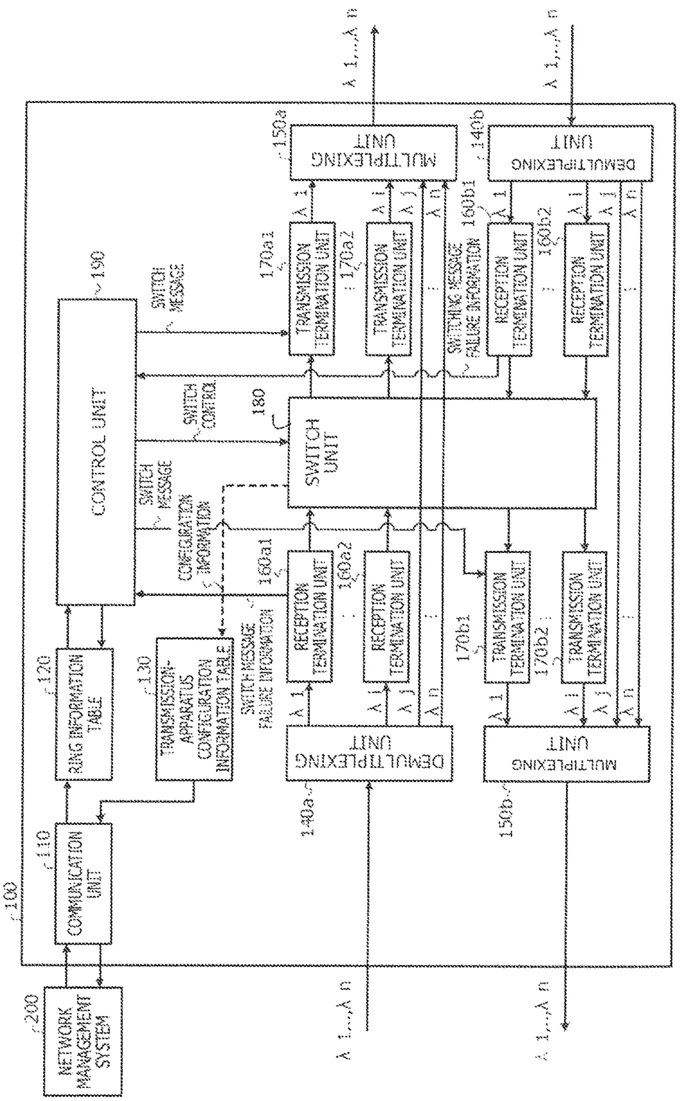


FIG. 2



100
NETWORK MANAGEMENT SYSTEM
200
COMMUNICATION UNIT
110
RING INFORMATION TABLE
120
TRANSMISSION-APPARATUS CONFIGURATION INFORMATION TABLE
130
CONTROL UNIT
190
SWITCH MESSAGE
SWITCH CONTROL
CONFIGURATION INFORMATION
SWITCH MESSAGE FAILURE INFORMATION
SWITCHING MESSAGE FAILURE INFORMATION
SWITCH UNIT
180
DEMULTIPLEXING UNIT
140a
140b
MULTIPLEXING UNIT
150a
150b
RECEPTION TERMINATION UNIT
160a1
160a2
160b1
160b2
TRANSMISSION TERMINATION UNIT
170a1
170a2
170b1
170b2
λ 1,...,λ n
λ 1
λ i
λ j
λ n

FIG. 3

120

WAVELENGTH	TRANSMISSION APPARATUS 100/TRANSMISSION LINE 300							
	100a	300a	100b	300b	100c	300c	100d	300d
λ_1	1	0	1	0	1	-1	1	0
λ_2	1	0	1	0	0	-1	1	0
λ_3	1	0	0	0	0	-1	1	0

FIG. 4

WAVELENGTH	CONFIGURATION INFORMATION
λ_1	1
λ_2	1
λ_3	0

FIG. 5

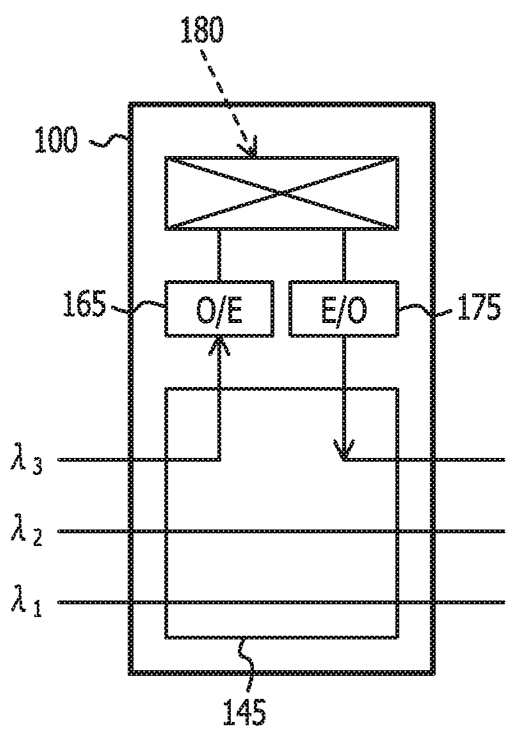


FIG. 6

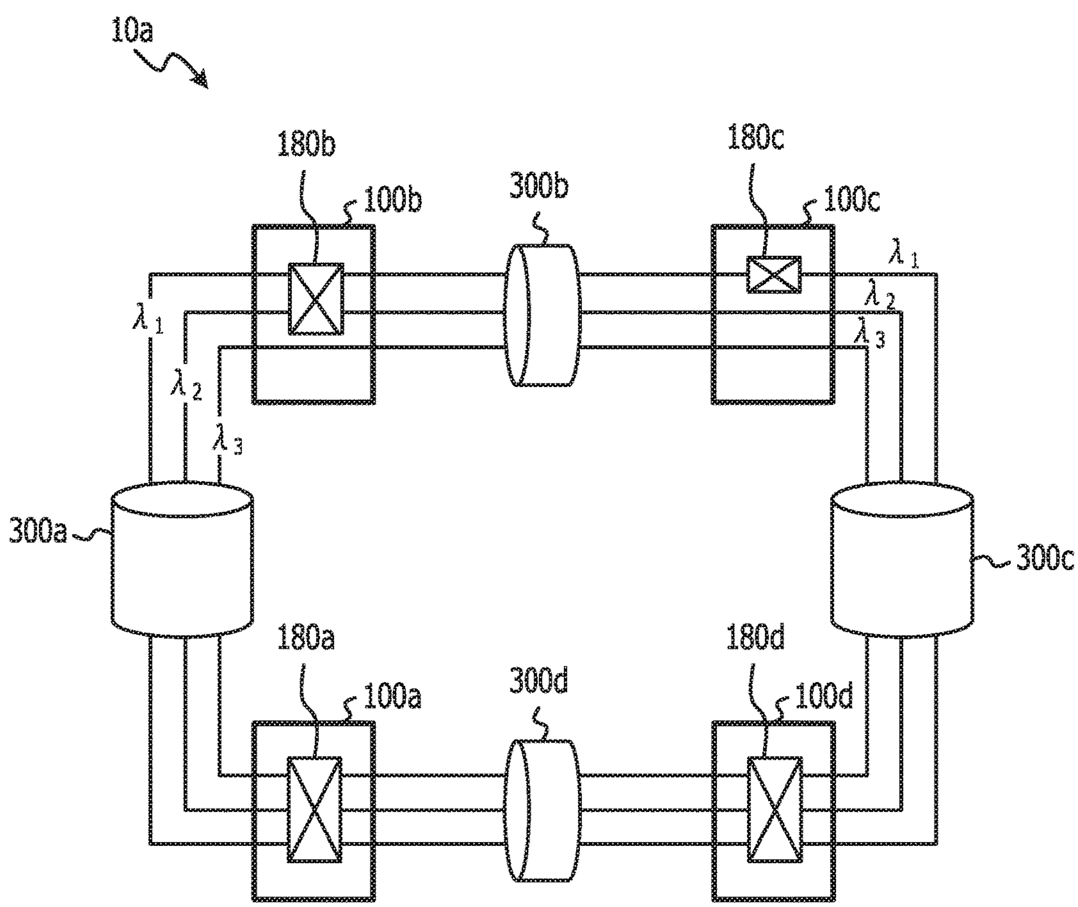

10a
180b
100b
300b
180c
100c
λ1
λ2
λ3
λ1
λ2
λ3
300a
300c
180a
100a
300d
180d
100d

FIG. 7

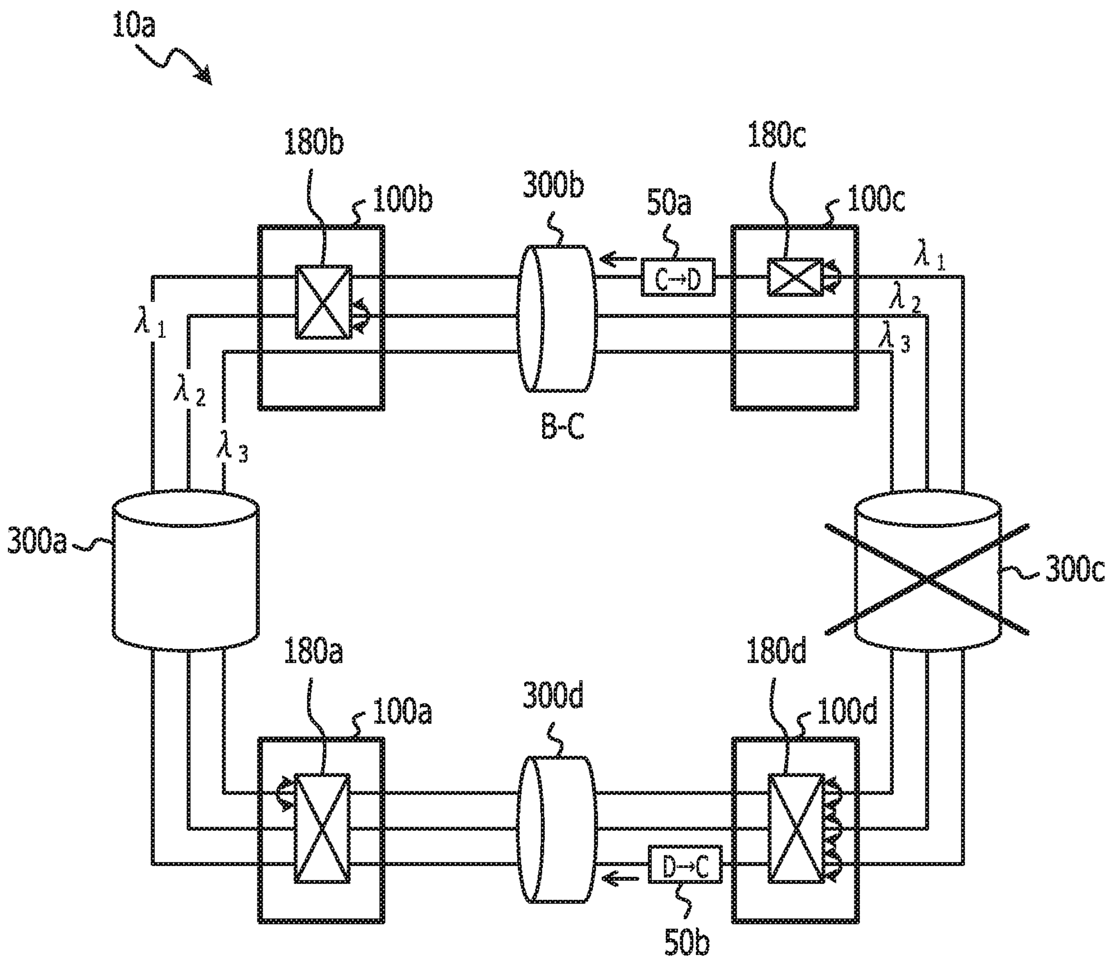

10a
180b
100b
300b
50a
C→D
180c
100c
λ1
λ2
λ3
B-C
300a
300c
180a
100a
300d
180d
100d
D→C
50b

FIG. 8

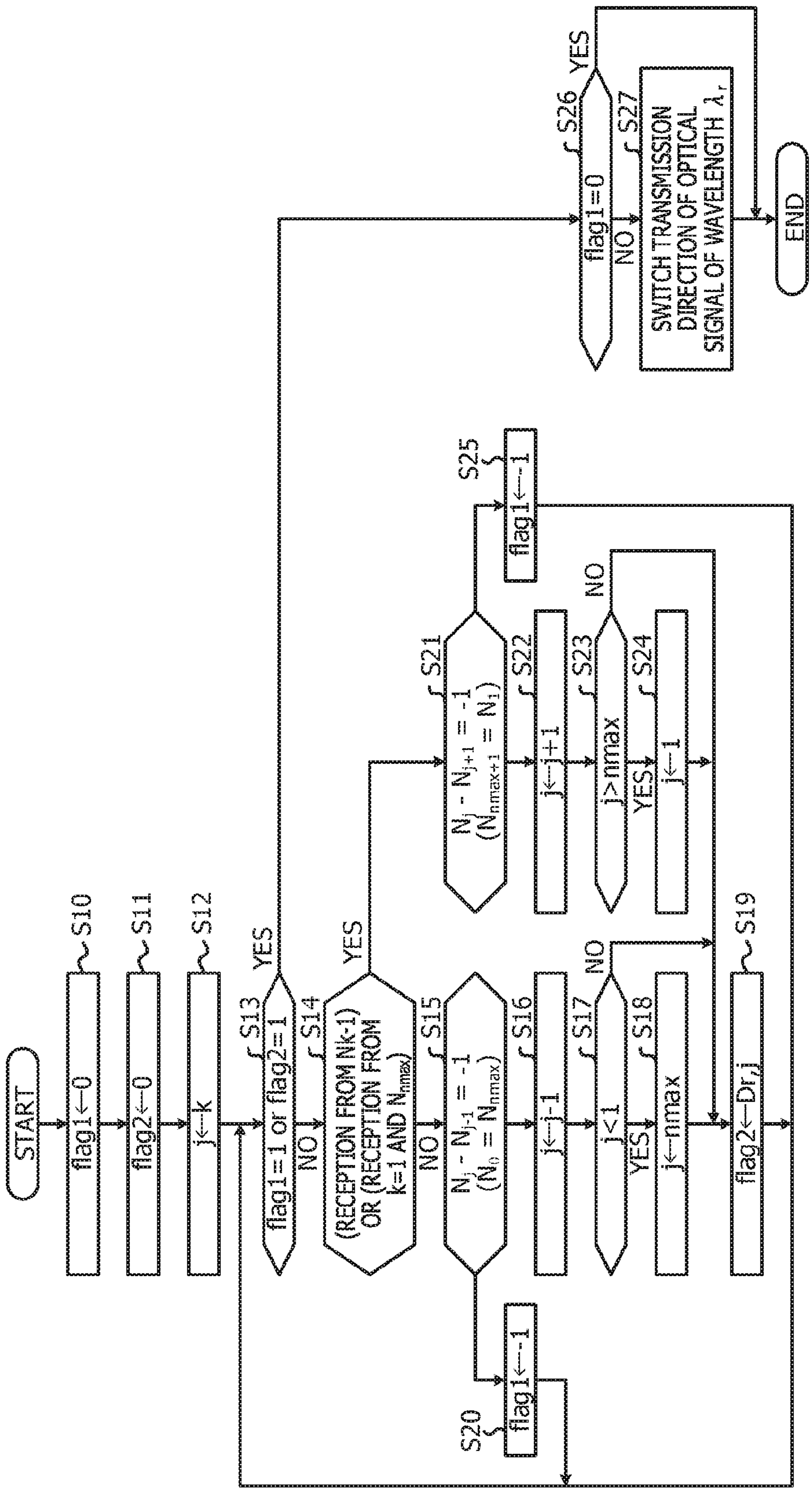

START
S10 flag1←0
S11 flag2←0
S12 j←k
S13 flag1=1 or flag2=1
YES
NO
S14 (RECEPTION FROM Nk-1) OR (RECEPTION FROM k=1 AND N_{nmax})
S15 N_j - N_{j-1} = -1 (N_0 = N_{nmax})
S16 j←j-1
S17 j<1
S18 j←nmax
S19 flag2←Dr,j
S20 flag1←-1
S21 N_j - N_{j+1} = -1 (N_{nmax+1} = N_1)
S22 j←j+1
S23 j>nmax
S24 j←1
S25 flag1←-1
S26 flag1=0
S27 SWITCH TRANSMISSION DIRECTION OF OPTICAL SIGNAL OF WAVELENGTH λ_r
END

FIG. 9

<table>
<tr><td colspan="8">APS1</td><td colspan="8">APS2</td><td colspan="8">APS3</td><td colspan="8">APS4</td></tr>
<tr><td>1</td><td>2</td><td>3</td><td>4</td><td>5</td><td>6</td><td>7</td><td>8</td><td>1</td><td>2</td><td>3</td><td>4</td><td>5</td><td>6</td><td>7</td><td>8</td><td>1</td><td>2</td><td>3</td><td>4</td><td>5</td><td>6</td><td>7</td><td>8</td><td>1</td><td>2</td><td>3</td><td>4</td><td>5</td><td>6</td><td>7</td><td>8</td></tr>
<tr><td colspan="5">BRIDGE REQUEST</td><td colspan="3">STATUS</td><td colspan="7">DESTINATION NODE ID</td><td>L/S</td><td colspan="7">SOURCE NODE ID</td><td>T/H</td><td colspan="8">PCC BYTE</td></tr>
</table>

FIG. 10B

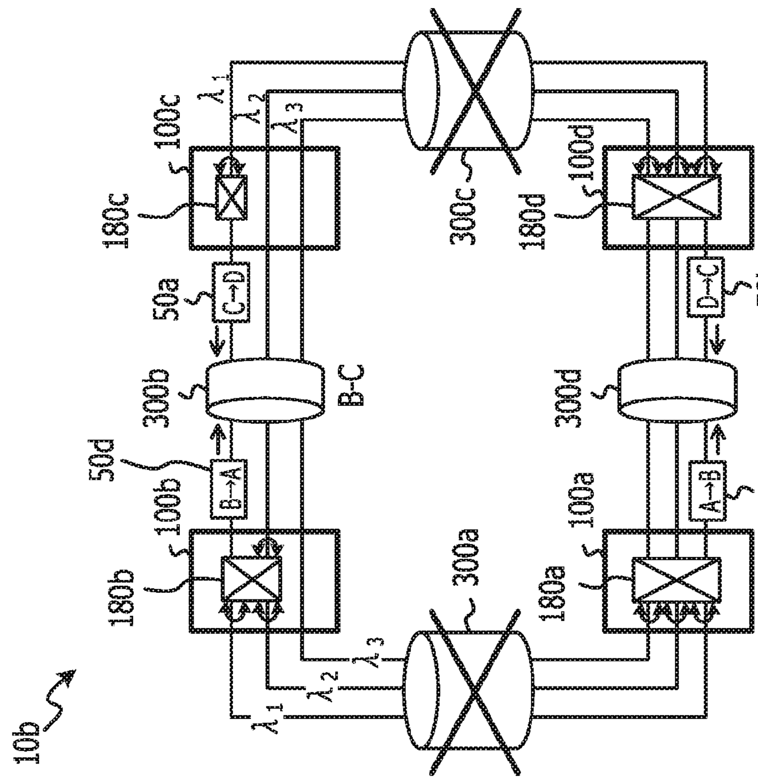


FIG. 10A

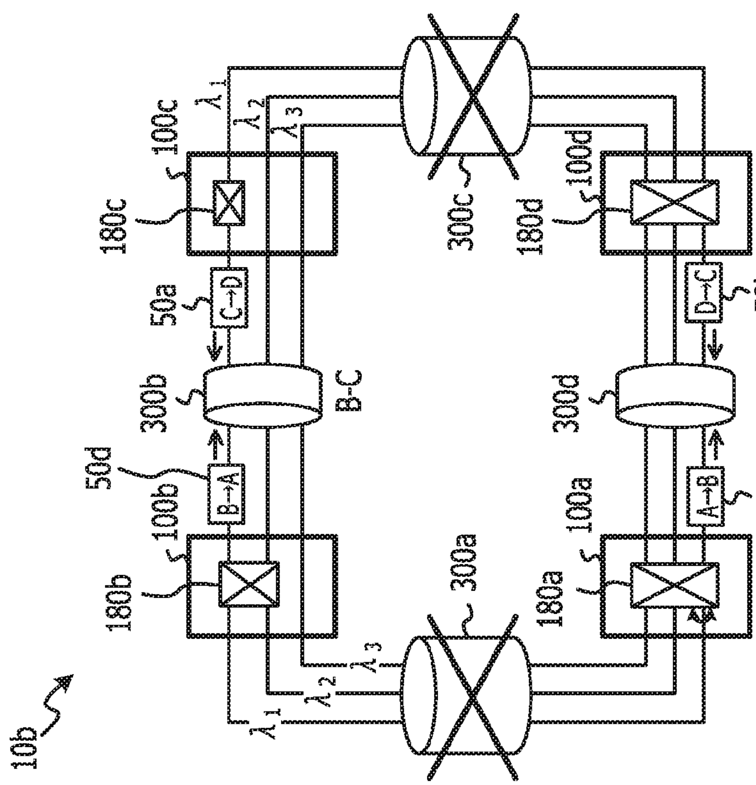


FIG. 11

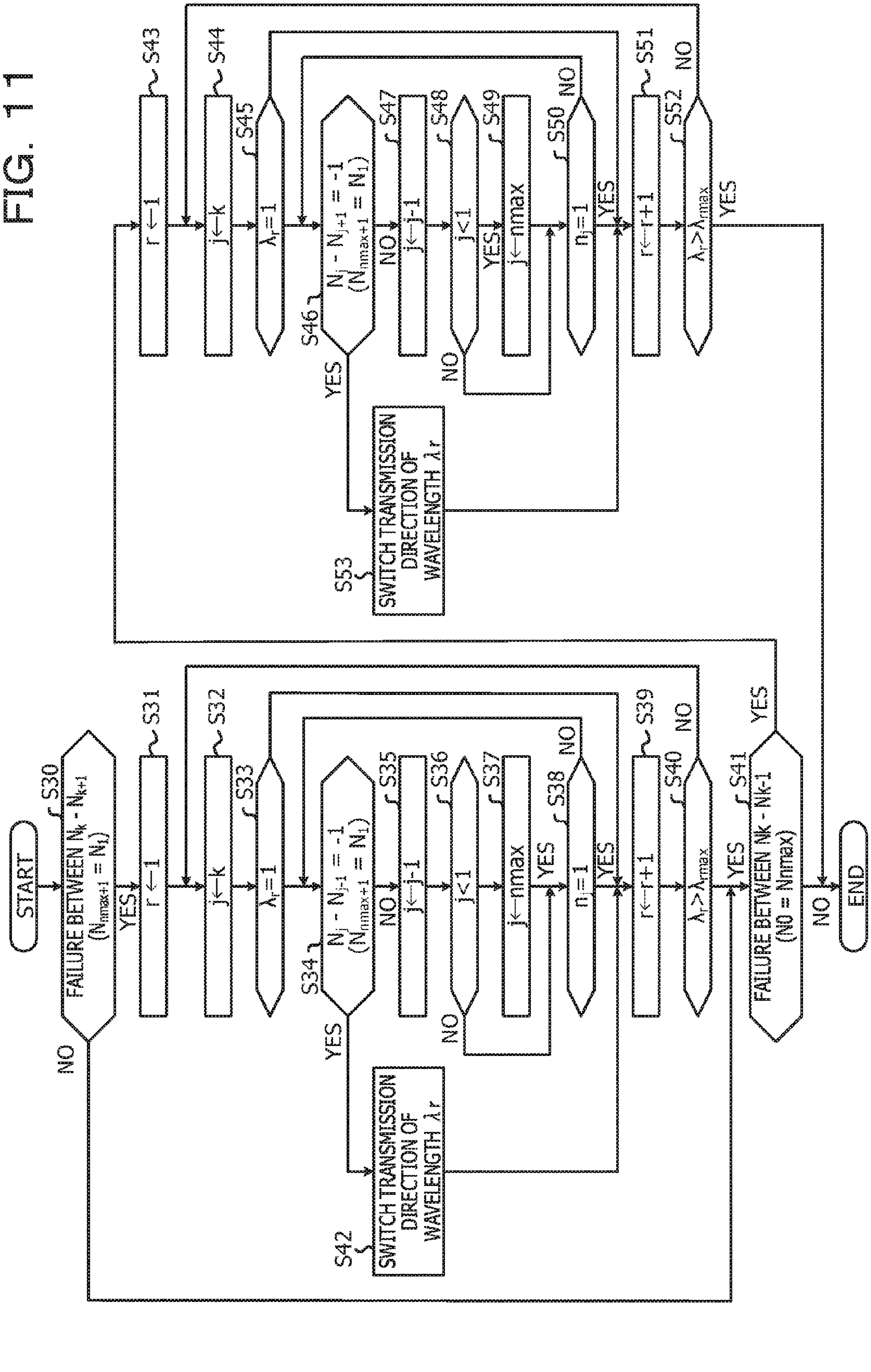

START
S30
FAILURE BETWEEN N_k - N_{k+1} (N_{nmax+1} = N_1)
YES
NO
S31
r ←1
S32
j←k
S33
λ_r=1
S34
N_j - N_{j-1} = -1 (N_{nmax+1} = N_1)
YES
NO
S35
j←j-1
S36
j<1
YES
NO
S37
j←nmax
S38
n_j=1
YES
NO
S39
r←r+1
S40
λ_r>λ_{rmax}
YES
NO
S41
FAILURE BETWEEN Nk - Nk-1 (N0 = Nnmax)
YES
NO
S42
SWITCH TRANSMISSION DIRECTION OF WAVELENGTH λ r
END
S43
r ←1
S44
j←k
S45
λ_r=1
S46
N_j - N_{j+1} = -1 (N_{nmax+1} = N_1)
YES
NO
S47
j←j-1
S48
j<1
YES
NO
S49
j←nmax
S50
n_j=1
YES
NO
S51
r←r+1
S52
λ_r>λ_{rmax}
YES
NO
S53
SWITCH TRANSMISSION DIRECTION OF WAVELENGTH λ r

FIG. 12

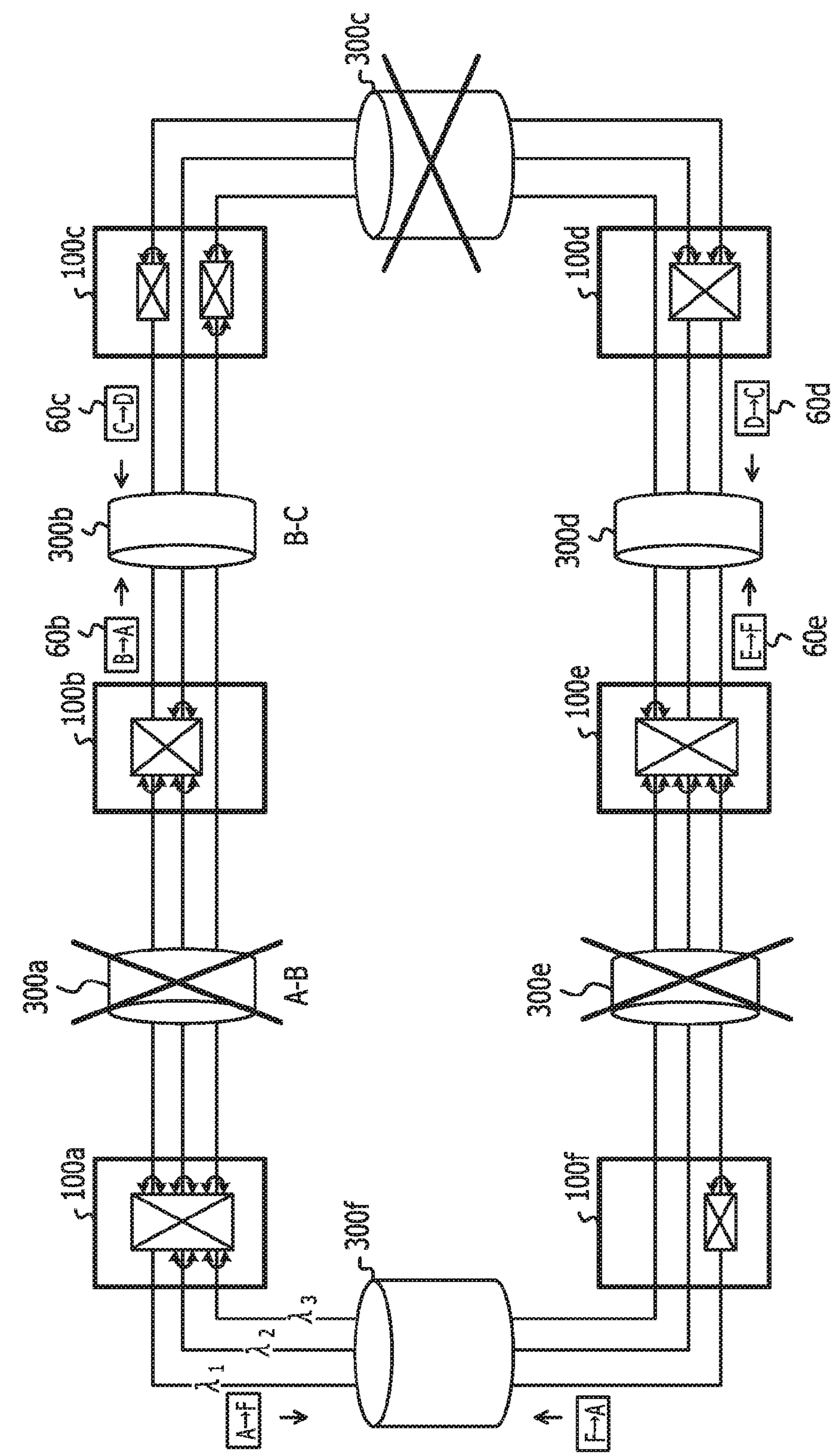

100a
100b
100c
100d
100e
100f
300a
300b
300c
300d
300e
300f
A-B
B-C
60b
60c
60d
60e
B→A
C→D
D→C
E→F
A→F
F→A
λ1
λ2
λ3

FIG. 13A

WAVELENGTH	TRANSMISSION APPARATUS (100)/TRANSMISSION LINE (300)											
	100a	300a	100b	300b	100c	300c	100d	300d	100e	300e	100f	300f
λ_1	1	-1	1	0	1	-1	1	0	1	0	1	0
λ_2	1	-1	1	0	0	-1	1	0	1	0	0	0
λ_3	1	-1	0	0	1	-1	0	0	1	0	0	0

FIG. 13B

WAVELENGTH	TRANSMISSION APPARATUS (100)/TRANSMISSION LINE (300)											
	100a	300a	100b	300b	100c	300c	100d	300d	100e	300e	100f	300f
λ_1	1	0	1	0	1	-1	1	0	1	-1	1	0
λ_2	1	0	1	0	0	-1	1	0	1	-1	0	0
λ_3	1	0	0	0	0	-1	1	0	1	-1	0	0

FIG. 14

120a

WAVELENGTH	TRANSMISSION APPARATUS100			
	100a	100b	100c	100d
λ_1	1	1	1	1
λ_2	1	1	0	1
λ_3	1	0	0	1

TRANSMISSION APPARATUS AND NETWORK CONTROL METHOD

CROSS-REFERENCE TO RELATED APPLICATION

This application is based upon and claims the benefit of priority of the prior Japanese Patent Application No. 2015-086313, filed on Apr. 20, 2015, the entire contents of which are incorporated herein by reference.

FIELD

The embodiments discussed herein are related to a transmission apparatus, and a network control method for network protection.

BACKGROUND

With recent increase in capacity of network, wavelength multiplexing network using an optical transport network (OTN, ITU-T G.709) technology has been commercialized.

In a protection method of the wavelength multiplexed OTN ring according to the ITU-T G.873.2, when a failure occurs in a certain link (transmission line), both end nodes (transmission apparatuses) of the failure link each detect the failure, and send a switch message to a link on the opposite side of the failure link. The switch message is a message to inform each node of switching a transmission direction of an optical signal.

The switch message has destination information on the other end node of the failure link. A node between both end nodes transfers the message as it is, and the message eventually reaches the other end node of the failure link. When receiving the message, the other end node of the failure link recognizes that the destination is the own node, and performs switching.

In a wavelength multiplexed ring network, the message for this protection operation is sent separately for each wavelength. However, when the number of multiplexed wavelengths increases, the number of switch messages sent among nodes increases, and a processing load in each node increases. This may delay a recovery from the failure.

In view of this, there is a technique called group protection in which, when a failure occurs in a link in the ring network, a plurality of wavelengths are regarded as one group, and one switch message is transmitted in the unit of group. According to this technique, when a failure occurs in the wavelengths in a group, one switch message is transmitted in the unit of group, and thus the transmission directions of optical signals of all the wavelengths are switched together by the end node of the link. This reduces the number of switch messages transmitted and received by the nodes.

Related techniques are disclosed in, for example, Japanese Laid-open Patent Publication Nos. 2013-030884 and 2013-046269.

SUMMARY

According to an aspect of the invention, a transmission apparatus being one of a plurality of transmission apparatuses included in a ring network, the transmission apparatus includes a switch configured to: transmit each of a first plurality of optical signals received from a first transmission apparatus to a second transmission apparatus, each of the first plurality optical signals having each of a plurality of wavelengths, the first transmission apparatus and the second transmission apparatus being included in the plurality of transmission apparatuses, the first transmission apparatus being one adjacent transmission apparatuses of the transmission apparatus in the rig network, the second transmission apparatus being another adjacent transmission apparatuses of the transmission apparatus in the ring network, and a processor configured to: receive a specified message from the first transmission apparatus, the specified message being for setting loopback for at least one wavelength in the ring network, the specified message being transmitted when a failure of at least one optical signal having the at least one wavelength is detected in a specified link of the ring network, the at least one wavelength being included in the plurality of wavelengths, and set a loopback to the switch, the loopback being set for a specified wavelength of the at least one wavelength when a specified optical signal having the specified wavelength is terminated by the switch and converted to an electrical signal and when the specified optical signal having the specified wavelength is not terminated and not converted to an electrical signal by any apparatus from the second transmission apparatus to the specified link in which the failure is detected, wherein after the loopback is set for the specified wavelength, when receiving an optical signal having the specified wavelength from the first transmission apparatus, the switch is configured to switch a wavelength of the received optical signal from the specified wavelength to a different wavelength and transmit an optical signal, corresponding to the received optical signal, having the different wavelength to the first transmission apparatus.

The object and advantages of the invention will be realized and attained by means of the elements and combinations particularly pointed out in the claims.

It is to be understood that both the foregoing general description and the following detailed description are exemplary and explanatory and are not restrictive of the invention, as claimed.

BRIEF DESCRIPTION OF DRAWINGS

FIG. **1** is a view illustrating an example of configuration of a ring network;

FIG. **2** is a view illustrating a first example of configuration of a transmission apparatuses;

FIG. **3** is a view illustrating an example of a ring information table;

FIG. **4** is a view illustrating an example of a transmission-apparatus configuration information table;

FIG. **5** is a view illustrating a second example of the configuration of the transmission apparatuses;

FIG. **6** is a view illustrating an example of configuration of a ring network;

FIG. **7** is a view illustrating an example in the case where a failure occurs in the ring network;

FIG. **8** is a view illustrating an example of a flowchart of a control unit;

FIG. **9** is a view illustrating an example of an APS signal;

FIG. **10**A is a view illustrating an example of a case where double failures occur in a ring network;

FIG. **10**B is a view illustrating the example of the case where the double failures occur in the ring network;

FIG. **11** is a view illustrating an example of a flowchart of a method of setting loopback until a switch message is transmitted;

FIG. **12** is a view illustrating an example of a case where triple failures occur in a ring network;

FIG. **13**A is a view illustrating an example of a ring information table of the transmission apparatuses in the ring network;

FIG. **13**B is a view illustrating an example of a ring information table of the transmission apparatuses in the ring network; and

FIG. **14** is a view illustrating an example of a ring information table in Embodiment 4.

DESCRIPTION OF EMBODIMENTS

Some configuration of the ring network, however, has a problem that when a switch message is sent in the unit of group at a failure of the network, transmission directions of optical signals are not accurately controlled.

For example, when added/dropped traffic is small in a node, the transmission apparatus (node) may pass optical signals of some wavelengths without terminating them to reduce costs of the transmission apparatus. In summary, an end node of a failure link passes a certain wavelength, while a node preceding the end node of the failure link terminates the wavelength.

In this case, when a switch message is transmitted in the unit of group, the preceding node is not enabled to switch transmission directions of optical signals, because the destination of the switch message is the end node of the failure link.

In this case, the end node of the failure link may just allow the optical signal transferred from the preceding node to pass therethrough and be transmitted to the failure link. That is, when the end node of the failure link passes the wavelength, the transmission directions of the optical signals are not correctly controlled.

The present disclosure is devised in consideration of such situation, and an object is to provide a transmission apparatus and a ring protection method that are capable of correctly controlling a transmission direction of an optical signal at an occurrence of a failure in a ring network including different transmission apparatuses, each terminating a different wavelength.

Preferred embodiments of the disclosed technology will be described below in detail with reference to attached drawings.

Embodiment 1

(Configuration of Ring Network)

First, configuration of a ring network will be described. FIG. **1** is a view illustrating exemplary configuration of a ring network **10**. As illustrated in FIG. **1**, the ring network **10** includes a plurality of transmission apparatuses **100***a* to **100***d* and a network management system **200**. When the transmission apparatuses **100***a* to **100***d* are not distinguished, they are simply referred to as transmission apparatus **100**. The number of the transmission apparatuses is 4 in this example, but are not limited to this number. Hereinafter, the transmission apparatus may be referred to as a node.

The transmission apparatus **100***a* and the transmission apparatus **100***b*, the transmission apparatus **100***b* and the transmission apparatus **100***c*, the transmission apparatus **100***c* and the transmission apparatus **100***d*, and the transmission apparatus **100***d* and the transmission apparatus **100***a* are connected to each other via respective optical fibers to form the ring network **10**. Optical signals having respective wavelengths are multiplexed and transmitted/received between the transmission apparatuses **100** in the ring network.

The transmission apparatuses **100** transmit and receive a signal and exchange information with the network management system **200**.

The network management system **200** collects information on the ring network from each transmission apparatus **100** and transmits the collection results to each transmission apparatus **100**.

(Configuration of Transmission Apparatus)

FIG. **2** is a view illustrating a first example of configuration of the transmission apparatus **100**. The transmission apparatus **100** includes a communication unit **110**, a ring information table **120**, a transmission-apparatus configuration information table **130**, demultiplexing units **140***a*, **140***b*, multiplexing units **150***a*, **150***b*, reception termination units **160***a*, **160***b*, transmission termination units **170***a*, **170***b*, a switch unit **180**, and a control unit **190**. The reception termination units **160***a***1**, **160***a***2** are collectively referred to as **160***a*. Similarly, the reception termination unit **160***b* and the transmission termination units **170***a*, **170***b* also represent their respective functions. When they are not distinguished, they are designated by only figures (for example, reception termination unit **160**).

The communication unit **110** transmits to the network management system **200** information on whether or not a transmission of each wavelength is terminated at the transmission apparatuses stored in the transmission-apparatus configuration information table **130**. The communication unit **110** receives configuration information on each transmission apparatus **100** constituting the ring network **10** and ring configuration information created based on transmission lines, and reports them to the ring information table **120**.

The ring information table **120** acquires the information on each transmission apparatus **100** constituting the ring network, which is acquired from the network management system **200**, from the communication unit **110**. The ring information table **120** has transmission line information in the transmission line (link) that interconnects the transmission apparatuses with a fiber or the like. Hereinafter, the transmission line that interconnects the transmission apparatuses may be referred to as a link.

The ring information table **120** is stored in a semiconductor memory device such as random access memory (RAM), read only memory (ROM), and flash memory, or a storage device such as a hard disc or an optical disc.

FIG. **3** illustrates an example of the ring information table **120**. As for the transmission apparatus **100** in the ring information table in FIG. **3**, the case where wavelength is terminated is indicated as "1", and the case where wavelength is not terminated is indicated as "0".

As for a transmission line **300**, the case where no failure occurs is indicated as "0", and the case where a failure occurs is indicated as "−1". The transmission line **300** refers to a section located between the transmission apparatuses **100**. For example, the transmission line **300***a* is located between the transmission apparatuses **100***a* and **100***b*, and represents the transmission line between the transmission apparatuses **100***a* and **100***b*. In the configuration of the ring network **10**, the transmission line **300***d* is located between the transmission apparatus **100***d* and the transmission apparatus **100***a*, and represents the transmission line between the transmission apparatus **100***d* and the transmission apparatus **100***a*. In a single failure, it is possible to perform protection processing without information on the transmission line **300**. However, in multiple failures, it is not possible to perform protection processing and thus, the information is used. This problem will be described in Embodiment 2.

The transmission-apparatus configuration information table **130** is updated by acquiring information (configuration information) from the switch unit **180** on whether or not each wavelength is terminated in the transmission apparatus **100**, and the communication unit **110** informs the network management system **200** of the result. FIG. **4** illustrates an example of the transmission-apparatus configuration information table **130**.

The transmission-apparatus configuration information table **130** is stored in a semiconductor memory device such as read only memory (RAM), read only memory (ROM), and flash memory, or a storage device such as a hard disc or an optical disc.

The demultiplexing unit **140** demultiplexes a multiplexed signal inputted to the transmission apparatus **100** into signals of respective wavelengths, and transmits them. The demultiplexing unit **140** includes AWG, for example.

The multiplexing unit **150** multiplexes signals of wavelengths including wavelengths inputted from the transmission termination unit **170** and unterminated wavelengths, and transmits them. The multiplexing unit **150** includes AWG, for example.

The reception termination unit **160** performs optical-electrical conversion on signal lights of wavelengths demultiplexed by the demultiplexing unit **140**, and if an automatic protection switching (APS) signal contains the switch message, the reception termination unit **160** informs the control unit **190** of the switch message. Other information is transmitted to the switch unit **180**. The reception termination unit **160** includes a photo diode, an ASIC, or the like, for example.

The transmission termination unit **170** performs electrical-optical conversion on a signal inputted from the switch unit **180** and transmits it to the multiplexing unit **150**. At this time, when instructed to transmit a switch message by the control unit **190**, the transmission termination unit **170** stores the information in the APS signal to make one wavelength (electrical-optical conversion). The transmission termination unit **170** includes a laser diode, an ASIC, or the like, for example.

The switch unit **180** switches the loop-back operation of each wavelength in response to an instruction of the control unit **190**, and outputs it to the transmission termination unit **170** for each wavelength. The switch unit **180** includes an integrated circuit such as an application specific integrated circuit (ASIC) and a field programmable gate array (FPGA).

When receiving a switch message and failure information from the reception termination unit, the control unit **190** updates the ring information table **120**. The control unit **190** controls the switch unit **180** based on the updated ring information table **120**. The control unit **190** issues an instruction to the transmission termination unit **170** when transmitting the information to another transmission apparatus **100**.

The control unit **190** is implemented by a central processing unit (CPU) performing a predetermined program. The functions of the control unit **190** are implemented by using an integrated circuit such as an ASIC and FPGA.

The transmission apparatus **100** may dynamically switch between terminated wavelength and passed wavelength. Referring to FIG. **5**, the case where the transmission apparatus **100** dynamically switches between the passed wavelength and the terminated wavelength will be described below. FIG. **5** is a view illustrating a second example of the configuration of the transmission apparatus in Embodiment 1. As illustrated in FIG. **5**, the transmission apparatus **100** includes a wavelength selection unit **145**, an O/E (Optical/Electricity) conversion unit **165**, an E/O (Electricity/Optical) conversion unit **175**, and the switch unit **180**. In FIG. **5**, a part of the transmission apparatus **100**, for example, the control unit **190**, the demultiplexing unit **140**, and the multiplexing unit **150**, are omitted.

The wavelength selection unit **145** is a processing unit that selects a terminated wavelength among wavelengths of the optical signal demultiplexed by the demultiplexing unit **140**. The wavelength selection unit **145** is capable of dynamically changing the terminated wavelength. The wavelength selection unit **145** includes a wavelength selection switch, for example.

For example, as illustrated in FIG. **5**, the wavelength selection unit **145** selects an optical signal of wavelength λ_3, and outputs the signal to the O/E conversion unit **165**. The wavelength selection unit **145** passes optical signals of wavelength λ_1 and wavelength λ_2. The wavelength selection unit **145** may select and terminate the wavelength λ_1 and the wavelength λ_2, and cancel selection of the wavelength λ_3 and pass the wavelength λ_3.

The O/E conversion unit **165** converts an optical signal of the wavelength **λ3** selected by the wavelength selection unit **145** into an electric signal. The O/E conversion unit **165** outputs the converted electric signal to the switch unit **180**. The switch unit **180** outputs an input signal to the E/O conversion unit **175** as an output signal. The E/O conversion unit **175** receives the electric signal corresponding to wavelength λ_3, which includes the switch message, from the switch unit **180**. The E/O conversion unit **175** converts the received electric signal into the optical signal of wavelength λ_3, and outputs the converted signal.

(Processing of Transmission Apparatus)

FIG. **6** is a view illustrating exemplary configuration of a ring network **10***a*. As illustrated in FIG. **6**, the ring network **10***a* includes transmission apparatuses **100***a* to **100***d* and links **300***a* to **300***d*. The transmission apparatus **100***a* and the transmission apparatus **100***b*, the transmission apparatus **100***b* and the transmission apparatus **100***c*, the transmission apparatus **100***c* and the transmission apparatus **100***d*, and the transmission apparatus **100***d* and the transmission apparatus **100***a* are connected via the links **300***a*, **300***b*, **300***c*, and **300***d*, respectively, to form the ring network **10***a*.

Although the network management system **200** is omitted in the ring network **10***a* in FIG. **6**, as illustrated in FIG. **1**, each transmission apparatus **100** exchanges information with the network management system **200**.

In FIG. **6**, the wavelength λ_1 to wavelength λ_3 are individually illustrated. However, the optical signals of wavelength λ_1 to wavelength λ_3 are multiplexed between the transmission apparatuses **100**. The demultiplexing unit **140**, the multiplexing unit **150**, and the transmission termination unit **170** are not illustrated.

In the transmission apparatuses **100** in FIG. **6**, termination depends on the wavelength, and the switch units **180** are illustrated for the terminated wavelengths of the optical signals. The wavelength of the optical signal terminated by the switch unit **180** varies among the transmission apparatuses **100**. For example, the switch unit **180***a* of the transmission apparatus **100***a* terminates the signals of wavelength λ_1 to wavelength λ_3. The switch unit **180***b* of the transmission apparatus **100***b* terminates the signals of the wavelength λ_1 and the wavelength λ_2, and passes the signal of the wavelength λ_3. The switch unit **180***c* of the transmission apparatus **100***c* terminates the signals of the wavelength λ_1, and passes the signals of the wavelength λ_2 and the wavelength λ_3. The switch unit **180***d* of the transmission apparatus **100***d* terminates the signals of the wavelength λ_1 to wavelength λ_3.

There will be described processing of the transmission apparatuses **100** executed when a failure occurs in the link **300***c* in the ring network **10***a* as illustrated in FIG. **7**. Because of the failure, the ring network **10***a* is unable to transmit and receive an optical signal between the transmission apparatus **100***c* and the transmission apparatus **100***d*.

The transmission apparatus **100** performs group protection using a plurality of wavelengths as one group. The group protection is processing of regarding a plurality of wavelengths as one group and recovering from a failure as the group.

When a failure occurs in the ring network **10***a*, the transmission apparatus **100** on one end of the link with the failure transmits a switch message addressed to the transmission apparatus **100** on the other end of the link, in the reverse direction to the link **300** with the failure.

Each transmission apparatus **100**, through which the switch message passes until the switch message reaches the transmission apparatus **100** on the other end of the link as destination, transfers the switch message to the next transmission apparatus **100**. The switch message eventually arrives at the transmission apparatus **100** on the other end of the link as destination.

Using one wavelength, the transmission apparatus **100** on one end of the link transmits one switch message to the transmission apparatus **100**. The transmission apparatus **100** on one end of link may select a wavelength to be terminated by the transmission apparatus **100** on both ends of the link with the failure, and transmit a switch message **50** using the selected wavelength. Each transmission apparatus **100** may terminate the wavelength to change the wavelength used in each link **300**.

For example, when a failure occurs in the link **300***c* as illustrated in FIG. **7**, using the optical signal of wavelength λ_1, the transmission apparatus **100***c* transmits the switch message **50***a* to the transmission apparatus **100***d*. The transmission apparatus **100***d* receives the switch message **50***a* via the transmission apparatus **100***b* and the transmission apparatus **100***a*. Meanwhile, using the optical signal of wavelength λ_1, the transmission apparatus **100***d* transmits the switch message **50***b* to the transmission apparatus **100***c*. The transmission apparatus **100***c* receives the switch message **50***b* via the transmission apparatus **100***a* and the transmission apparatus **100***b*. The transmission apparatus **100***c* or the transmission apparatus **100***d* transmits the switch message **50** using the wavelength λ_1, but may transmit the switch message **50** using another wavelength terminated by the transmission apparatus **100***c* and the transmission apparatus **100***d*.

After receiving the switch message **50**, the transmission apparatus **100** updates information on disabled transmission to the link **300**, based on the switch message **50**. Upon updating, the transmission apparatus **100** refers to the ring information table **120**, and determines whether or not the transmission apparatus **100** loops back the optical signal for each wavelength.

Next, there will be described a specific example of processing of looping back the optical signal in each transmission apparatus **100**. The optical signals of wavelength λ_1 to wavelength λ_3 transmitted from the transmission apparatus **100***d* to the transmission apparatus **100***c* via the transmission apparatus **100***a* and the transmission apparatus **100***b* are processed as follows.

For example, the transmission apparatus **100***c* that receives the switch message **50***b* from the transmission apparatus **100***d* via the transmission apparatus **100***a* and the transmission apparatus **100***b* updates all wavelengths for the link **300***c* in the ring information table **120** to "−1" (transmission is disabled). Then, since the destination node of the switch message **50***b* is the transmission apparatus **100***c* itself, the transmission apparatus **100***c* loops back the optical signal of wavelength λ_1.

The transmission apparatus **100***b* that receives the switch message **50***b* from the transmission apparatus **100***d* via the transmission apparatus **100***a* updates all wavelengths in the link **300***c* in the ring information table **120** to "−1" (transmission is disabled). In the record of wavelength λ_2, since the value of the own node is "1", the value of the transmission apparatus **100***c* as the destination node is "0", and the value of the link **300***c* is "−1", the transmission apparatus **100***b* itself loops back the optical signal of wavelength λ_2.

The transmission apparatus **100***a* that receives the switch message **50***b* from the transmission apparatus **100***d* updates all wavelengths in the link **300***c* in the ring information table **120** to "−1". In the record of wavelength λ_3, since the value of the own node is "1", the value of the transmission apparatus **100***b* is "0", the value of the transmission apparatus **100***c* as the destination node is "0", and the value of the link **300***c* is "−1", the transmission apparatus **100***a* itself loops back the optical signal of wavelength λ_3.

As for the optical signals of wavelength λ_1 to wavelength λ_3 transmitted from the transmission apparatus **100***c* toward the transmission apparatus **100***d* via the transmission apparatus **100***b* and the transmission apparatus **100***a*, all values of the transmission apparatus **100***d* are "1", and the transmission apparatus **100***d* terminates all optical signals of wavelength λ_1 to wavelength λ_3. Thus, when receiving the switch message **50***a*, the transmission apparatus **100***d* loops back each of the optical signals of wavelength λ_1 to wavelength λ_3.

Referring to FIG. **8**, there will be described processing of the control unit **190** of the transmission apparatus **100** in the case where a failure occurs in the ring network.

FIG. **8** illustrates an example of a flowchart of processing of the control unit **190**. FIG. **8** is an example of a flowchart illustrating processing of wavelength λ_r in the case where the transmission apparatus **100** receives the switch message.

The switch message for the transmission apparatus **100** as destination is terminated by each transmission apparatus. The transmission apparatus **100** executes the flowchart in FIG. **8** also for the wavelength other than the wavelength λ_r. The flow chart in FIG. **8** represents the transmission apparatus **100** using transmission apparatus number k (k=1, 2, 3, . . . nmax).

The link **300** is represented by two transmission apparatuses **100** such as N_j-N_{j+1}. N_j-N_{j+1} indicates that a signal is transmitted from N_j toward N_{j+1}.

The control unit **190** stores 0 in "flag**1**" and "flag**2**" (steps S**10**, S**11**). The "flag**1**" and the "flag**2**" each are a variable for storing values of the link **300** and the transmission apparatus **100**, which are acquired from the ring information table **120**. A value "−1" of "flag**1**" indicates that a failure occurs in the link **300** and transmission is disabled. A value "1" of "flag**2**" indicates that the transmission apparatus **100** terminates wavelength λ_r.

The control unit **190** stores a variable k in j (step S**12**). The values of flag**1** and flag**2** are checked (step S**13**). When both the values of flag**1** and flag**2** are 0 (step S**13**; No), the reception direction of the switch message **50** is checked (step S**14**).

When the switch message **50** is received from the N_{k+1} (step S**14**; No), the state of the link **300** between N_j-N_{j-1} is checked (step S**15**). Here, in the case of j=1, N_{j-1} becomes N_0. However, in the configuration of the ring network, N_{nmax} precedes N_1 and thus, N_0 is N_{nmax} and N_1-N_0 becomes N_1-N_{nmax}.

In the case of N_j-N_{j-1}=0 (step S**15**; No (no failure)), j−1 is stored in j (step S**16**). It is determined whether or not j is smaller than 1 (step S**17**), and when j is smaller than 1 (step S**17**: Yes), nmax is stored in j (step S**18**), the processing proceeds to step S**19**. When j is 1 or more (step S**17**: No), the processing proceeds to step S**19**.

The control unit **190** stores a variable "Dr, j" in the variable "flag**2**" (step S**19**), the processing proceeds to step S**13**. The variable "Dr, j" is a variable corresponding to the transmission apparatus j in the record of the wavelength λ_r in the ring information table **120**. When the node j does not terminate the wavelength λ_r, the control unit **190** stores "0" extracted from the ring information table **120** in the variable "Dr, j". When the node j terminates the wavelength λ_r, the control unit **190** stores "1" extracted from the ring information table **120** in the variable "Dr, j".

In the case of N_j-N_{j-1}=−1 (step S**15**; Yes (failure)), "−1" is stored in flag**1** (step S**20**), the processing proceeds to step S**13**.

When the signal is received from the N_{k-1} in step S**14** (step S**14**; Yes), the state of the link **300** between N_j-N_{j+1} is checked (step S**21**). Here, in the case of j=nmax, N_{j+1} becomes N_{nmax+1}. However, in the configuration of the ring network **10***a*, N_{nmax} precedes N_1 and thus, N_{nmax+1} is N_1 and N_{nmax}-N_{nmax+1} becomes N_{nmax}-N_1.

In the case of N_j-N_{j+1}=0 (step S**21**; No (no failure)), "j+1" is stored in j (step S**22**). It is determined whether or not j is larger than nmax (step S**23**), and when j is larger than nmax (step S**23**: Yes), 1 is stored in j (step S**24**), the processing proceeds to step S**19**. When j is 1 or more (step S**23**: No), the processing proceeds to step S**19**.

In the case of N_j-N_{j+1}=−1 (step S**21**; Yes (failure)), "−1" is stored in flag**1** (step S**25**), the processing proceeds to step S**13**.

In the case of flag**1**=−1 or flag**2**=1 in step S**13** (Yes in step S**13**), the processing proceeds to step S**26**, it is determined whether or not flag**1**=0 (step S**26**).

In the case of flag**1**=0 (step S**26**; Yes), the processing is finished. In the case of flag**1**=−1 (step S**26**; No), the processing proceeds to step S**27**, the transmission direction of the optical signal of wavelength λ_r is switched (step S**27**), the processing is finished.

In the case where the ring information table **120** has information only on the transmission apparatus **100**, switching control is performed based on the failure information of the switch message **50** and the wavelength terminated by the transmission apparatus **100**.

(Description of Switching Control in Ring Network)

In the BLSR (Bi-directional Line Switched Ring) used in this method, use for normal processing and use for protection are separated in the fiber. For example, when the wavelengths λ_1 to λ_6 are multiplexed, the wavelengths λ_1 to λ_3 are used for normal processing, and the wavelengths λ_4 to λ_6 are used for protection. When a failure occurs in the transmission line, the transmission apparatus **100** on one end of the failure transmission line converts the wavelength λ_1 into the protection wavelength λ_4, and transmits the converted signal of protection wavelength λ_4 to the other end of the failure transmission line in the reverse direction.

The transmission apparatus **100** that does not perform switching control transmits a signal as usual. For example, in the case where the transmission apparatus **100***b* transmits a signal of wavelength λ_1 to the transmission apparatus **100***a* via the transmission apparatuses **100***c*, **100***d* in FIG. **6**, when a failure occurs in the transmission line **100***c*, as illustrated in FIG. **7**, each transmission apparatus **100** performs switching control. Although only the wavelengths used for normal processing are illustrated in FIG. **6**, the wavelengths for the protection are terminated in the same manner.

The transmission apparatus **100***b* transmits the signal of wavelength λ_1 as usual. The transmission apparatus **100***c* receives the signal of wavelength λ_1, converts the signal into a signal for protection (recovery) wavelength λ_4, and transmits the converted signal so as not to pass through the transmission line **300** with the failure.

The signal of protection wavelength λ_4 transmitted from the transmission apparatus **100***c* is transmitted to the transmission apparatus **100***d*, is converted into a signal of the wavelength λ_1 for normal processing at the transmission apparatus **100***d*, which is then transmitted to the transmission apparatus **100***a*.

As described above, when a failure occurs, the transmission apparatuses **100** on both ends of the transmission line **300** with the failure perform the same operation as usual using the protection wavelength.

(Description of ASP Byte Transferring Switch Message)

Referring to FIG. **9**, an APS signal used to transfer the switch message **50** will be described. FIG. **9** is a view illustrating an example of the APS signal. The example in FIG. **9** conforms to the specification in ITU-TG.873.2. As illustrated in FIG. **9**, ASP bytes includes four bytes of APS**1** to APS**4**.

For example, APS**1** of the APS bytes includes "Bridge Request". For example, when a failure occurs in the link **300** of the ring network **10***a*, the transmission apparatus **100** stores a signal "SF-R (Signal Fail Ring)" in "Bridge Request" of the APS byte.

APS**2** includes "Destination Node ID". The transmission apparatus **100** stores ID (Identification) of the destination transmission apparatus **100** in "Destination Node ID" of APS**2**.

APS**3** includes "Source Node ID". The transmission apparatus **100** stores ID of the source transmission apparatus **100** in "Source Node ID" of APS**3**.

Although "SF-R" is stored in "Bridge Request" of APS**1** in this example, "SF-R" may be stored in another signal.

(Generation and Update of Ring Information Table)

Generation of the ring information table **120** will be described. The ring information table **120** includes information on whether or not the transmission apparatus **100** terminates the wavelength λ_r and information indicating the state of each link **300**.

In the ring network **10***a* as illustrated in FIG. **6**, the network management system **200** collects transmission-apparatus configuration information of each transmission apparatus **100** from the each of the transmission apparatus **100***a* to **100***d*. For example, configuration information stored in the transmission-apparatus configuration information table **130** of each transmission apparatus **100** is extracted.

The configuration information on transmission apparatus, which is collected by the network management system **200**, is combined with the initial state of each link **300** (in the initial state, all links have no failure (0)) to generate the initial ring information table **120**. At this time, the transmission apparatus **100***a*, the link **300***a* (between the transmission apparatuses **100***a* and **100***b*), the transmission apparatus **100***b*, . . . are described in a ring-like manner as illustrated in FIG. **6** in the ring information table **120**.

Next, specific processing of generating the ring information table **120** in each transmission apparatus **100** will be described. For example, given that the transmission apparatus **100***b* has the configuration as illustrated in FIG. **4**, the transmission apparatus **100***b* stores configuration information"1, 1, 0" corresponding to the wavelength λ_1, wavelength λ_2, wavelength λ_3. The network management system **200** acquires the configuration information "1, 1, 0" from the transmission apparatus **100***b* via network.

The network management system **200** stores the acquired configuration information"1, 1, 0" on the transmission apparatus **100***b* in the row for the transmission apparatus **100***b*. Similarly, the network management system **200** acquire the configuration information from the transmission apparatuses **100***a*, **100***c*, and **100***d*, and performs processing in the same manner.

The network management system **200** transmits the configuration information acquired from the transmission apparatuses to the each transmission apparatus **100**. When receiving new transmission-apparatus configuration information from the network management system **200**, each transmission apparatus **100** updates information based on the received ring configuration information. When a failure occurs in the link **300** on updating, only information on the transmission apparatus **100** may be updated while keeping failure information of the link unchanged.

When a new transmission apparatus **100** is added to the ring network **10***a*, the network management system **200** adds rows for the new transmission apparatus **100** and an accompanying link **300** in the ring information table **120**.

Next, updating of the link **300** will be described using a specific example. For example, as illustrated in FIG. **7**, assume that the link **300***c* unable to make communication due to a failure. The transmission apparatus **100***c* that detects the failure (based on reception of no signal) transmits the switch message **50***a* to the transmission apparatus **100***d* without using the link **300***c*.

When the transmission apparatus **100***b* receives this signal, the transmission apparatus **100***b* finds that the transmission line **300***c* has a failure according to the switch message **50***a*. When finding that the link **300***c* has the failure, the transmission apparatus **100***b* updates the wavelength for the corresponding transmission line **300** in the ring information table (when all lines have the failure (such as cutoff), all wavelengths) to "−1".

Similarly, the transmission apparatus **100***a* also updates its table, when receiving the signal. The transmission apparatuses **100***c*, **100***d* on both ends of the transmission line **300***c* with the failure may update their tables when detecting a failure or when receiving the switch message **50**.

In this manner, each transmission apparatus **100** and each link **300** in the ring information table **120** are updated.

As described above, in Embodiment 1, in the ring network **10***a* in which some wavelength is not terminated and passes the transmission apparatus **100**, with even group protection, loopback can be correctly switched for each wavelength of each transmission apparatus. As compared with protection of each transmission apparatus **100**, loads on transmission and reception processing of the switch message are reduced. For example, in the case of WDM transmission of 88 wavelengths, it is possible to set loopback with 1/88 of processings at maximum.

Embodiment 2

In Embodiment 2, a situation when double failures occur is described.

A ring network **10***b* in FIGS. **10**A and **10**B has the same configuration as the ring network **10***a*, and failures occurs in two links **300**, link **300***a* and the link **300***c*.

In the ring network **10***b*, in the case where the ring information table **120** has only information on each transmission apparatus **100**, when the switch message **50** is received, switching control as illustrated in FIGS. **10**A and **10**B is performed in consideration on only the transmission line that receives the switch message **50**, and each transmission apparatus **100** is unable to perform correct switching. Therefore, information on each transmission line **300** is desired.

FIG. **10**B illustrates switching control using information on the transmission line **300** as well. In FIG. **10**B, the transmission apparatus **100***b* detects a failure in the transmission line **300***a*, updates all wavelengths in the link **300***a* of its own table to "−1", and transmits the switch message **50***d* in the order of the transmission apparatuses **100***b*, **100***c*, **100***d*, and **100***a*. The transmission apparatus **100***b* receives the switch message **50***a* addressed to the transmission apparatus **100***d* from the transmission apparatus **100***c*. When receiving the switch message **50***a*, the transmission apparatus **100***b* updates the transmission line **300***c* in the ring information table **120** to "−1".

The transmission apparatus **100***b* receives the switch message **50**, updates information on the link **300** and then, make a determination on switching. At this time, in the ring information table **120**, for example, values of the links **300***a*, **300***c* are "−1".

Since the transmission apparatus **100***b* has received the switch message **50***a* from the C to D, the transmission apparatus **100***b* checks each wavelength terminated by the transmission apparatus **100***b*, like checking the link **300***a*, then the transmission apparatus **100***a*, and so on. For example, the wavelength λ_1 is switched because the link **300***a* is "−1". Similarly, the wavelength λ_2 is switched because the link **300***a* is "−1", too.

However, in the state illustrated in FIG. **10**B, since a failure occurs in the link **300***a*, the transmission apparatus **100***b* is unable to receive the switch message **50***b* from the transmission apparatus **100***d* to the transmission apparatus **100***c* (transmission direction: transmission apparatus **100***d*, **100***a*, **100***b*, **100***c*). Thus, the transmission apparatus **100***b* is unable to perform switching in the direction of the transmission apparatus **100***c*.

Accordingly, to perform correct switching even in the above case of the transmission apparatus **100***b*, each transmission apparatus **100** checks presence or absence of loopback for each wavelength λ_r when transmitting the switch message **50**.

For example, in the case illustrated in FIG. **10**B, presence or absence of loopback is searched in the transmission direction using information in the ring information configuration table **120**, before the transmission apparatus **100***b* transmits the switch message **50***d*. In the transmission apparatus **100***b*, the link **300***b*, the transmission apparatus **100***c*, . . . are searched. In the transmission apparatus **100***b*, the wavelength λ_1 is not switched because the link **300***b* is "0", and the transmission apparatus **100***c* is "1". The wavelength λ_2 is switched because the link **300***b* is "0", the transmission apparatus **100***c* is "0", and the link **300***c* is "−1".

Referring to an example of flowchart in FIG. **11**, a method of setting loopback before the transmission apparatus **100** transmits the switch message **50**. It is determined whether or not there is a failure between N_k and N_{k+1} or between N_k and N_{k-1}. (step **S30**, step **S41**). Here, N_k denotes the transmission apparatus **100**, and k is a number of the own node. The own node number is applied to the ring network **10***b* in which the transmission apparatuses **100** are connected to each other in a ring-like manner in the order of 1, 2, 3, . . . , nmax.

When no failure occurs (step S**30** and step S**41**; No), the processing is finished. However, in FIG. **11**, processing between N_k and N_{k+1} is finished and then, processing between N_k and N_{k-1} is executed. Thus, when the result in step S**30** is No, the processing proceeds to step S**41**. The processing between N_k and N_{k-1} may be executed first.

When a failure between N_k and N_{k+1} is detected (step S**30**; Yes), "1" and "k" are stored in r and j, respectively (step S**31**, step S**32**), it is determined whether or not a transmission apparatus N; terminates λ_r (step S**33**). When λ_r is terminated (step S**33**; Yes), the state of the transmission line **300** between N; and N_{j-1} is checked (step S**34**). Here, in the case of j=1, N_{j-1} becomes N_0. However, in the configuration of the ring network, N_{nmax} precedes N_1 and thus, N_0 is N_{nmax} and N_1-N_0 becomes N_1-N_{nmax}.

In the case of N_j-N_{j-1}=0 (step S**34**; No (no failure)), j−1 is stored in j (step S**35**). It is determined whether or not j is smaller than 1, (step S**36**). When j is smaller than 1 (step S**36**; Yes), nmax is store in j (step S**37**), the processing proceeds to step S**38**. When j is 1 or more (step S**36**; No), the processing proceeds to step S**38**.

It is determined whether or not the transmission apparatus N; terminates the wavelength λ_r (step S**38**). When the transmission apparatus N; does not terminates the wavelength λ_r (No in step S**38**), the processing proceeds to step S**34**. When the transmission apparatus N_j terminates the wavelength λ_r, the processing proceeds to step S**39**.

In the case of N_j−N_{j-1}=−1 (step S**34**; Yes (failure)), the transmission direction of the optical signal of wavelength λ_r is switched (step S**42**), and the processing proceeds to step S**39**.

To determine presence or absence of switching of the next wavelength, r+1 is stored in r (step S**39**). It is determined whether or not the wavelength is used for the stored wavelength (step S**40**).

When the stored wavelength is used (step S**40**; No), the processing proceeds to step S**32**. When the stored wavelength is not used (step S**40**; Yes), the processing of the failure between N_k and N_{k+1} is finished, and the processing proceeds to step S**41**. However, when processing in step S**41** and subsequent steps is performed, the processing before transmission is finished.

When a failure between N_k and N_{k-1} is detected (step S**41**; Yes), **1** and k are stored in r and j, respectively (step S**43**, step S**44**), it is determined whether or not the transmission apparatus terminates the wavelength λ_r (step S**45**). When the transmission apparatus terminates λ_r (step S**45**; Yes), the state of the transmission line between N; and N_{j+1} is checked (step S**46**). Here, in the case of j=N_{nmax}, N_{j+1} becomes N_{nmax+1}. However, in the ring network, N_{nmax} precedes N_1 and thus, N_{nmax+1} is N_1, and N_{nmax}-N_{nmax+1} becomes N_{nmax}-N_1.

In the case of N_j-N_{j+1}=0 (step S**46**; No (no failure)), j+1 is stored in j (step S**47**). It is determined whether or not j is larger than nmax (step S**48**), and when j is larger than nmax (step S**48**; Yes), 1 is stored in j (step S**49**), the processing proceeds to step S**50**. When j is nmax or less (step S**48**; No), the processing proceeds to step S**50**.

It is determined whether or not the transmission apparatus N; terminates the wavelength λ_r (step S**50**). When the transmission apparatus N; does not terminate the wavelength λ_r (step S**50**; No), the processing proceeds to step S**46**. When the transmission apparatus N_j terminates the wavelength λ_r, the processing proceeds to step S**51**.

In the case of N_j-N_{j+1}=−1 (step S**46**; Yes (failure)), the transmission direction of the optical signal of wavelength λ_r is switched (step S**53**), the processing proceeds to step S**51**.

To determine presence or absence of switching of the next wavelength, "r+1" is stored in r (step S**51**). It is determined whether or not the wavelength is used for the stored wavelength (step S**52**).

When the wavelength λ_r is used (step S**52**; No), the processing proceeds to step S**44**. When the stored wavelength is not used (step S**52**; Yes), processing of the failure of N_k-N_{k+1} is finished to finish processing. However, when processing in step S**41** and subsequent steps is executed first, the processing proceeds to step S**32**.

As described above, by determining presence or absence of loopback at transmission, proper loopback can be achieved.

Next, a method of reducing malfunction in protection will be described. As described above, in the BLSR used in this method, use for normal processing and use for protection are separated in the fiber.

At occurrence of multiple failures, a signal may not be transmitted from the source transmission apparatus **100** to the destination transmission apparatus **100**, and the transmission apparatus **100** in between performs loopback. To reduce malfunction at this time, the operation referred to as Squelch is performed based on the APS signal.

Squelch means a function of blocking noise and unnecessary transmission from the party at the other end to put into information-free state.

Use of squelch reduces malfunction that a signal is transmitted to the transmission apparatus **100** other than the destination transmission apparatus **100** at multiple failures.

As described above, in Embodiment 2, in the ring network **10***b* in which some wavelength is not terminated and passes the node, correct protection is achieved for each wavelength even at double failures.

Embodiment 3

Embodiment 2 describes a protection method in the case of double failures. Embodiment 3 describes processing at triple failures, and application at multiple failures. A ring network **10***c* illustrated in FIG. **12** has triple failures. In the ring network **10***c* in FIG. **12**, the transmission apparatus **100***a* to **100***f* are connected to each other in a ring-like manner, and the transmission apparatuses **100** are connected to each other via the link **300**. Although FIG. **12** illustrates three wavelengths, the number of wavelength is not limited to three. Although the wavelengths are separately illustrated, signals having the respective wavelengths are multiplexed and transmitted between the transmission apparatuses **100**.

FIG. **12** illustrates the state where failures occur in the links **300***a*, **300***c*, and **300***e* in the ring network **10***c*.

The ring information table **120** in the transmission apparatus **100***b* in the state illustrated in FIG. **12** becomes the table as illustrated in FIG. **13**A. When detecting the failure in the link **300***a*, the transmission apparatus **100***b* updates the link **300***a* of the ring information table **120** of its own node to "−1".

When receiving a switch message **60***c* from the transmission apparatus **100***c*, the transmission apparatus **100***b* update the link **300***c* to "−1", and determines presence or absence of loopback of the wavelengths λ_1, λ_2 terminated by the transmission apparatus **100***b*. Since the link **300***a* is "−1" in the ring information table **120** of the transmission apparatus **100***b* illustrated in FIG. **13**A, the transmission apparatus **100***b* set loopback to all of the terminated wavelengths.

Before transmission of a switch message **60***b*, the transmission apparatus **100***b* set loopback of the wavelength λ_2 by referring to the ring information table **120** of the transmission apparatus **100***b* in FIG. **13**A on presence or absence of switching in the transmission direction.

When detecting a failure in the link **300***e*, the transmission apparatus **100***e* updates the link **300***e* in the ring information table **120** of the own node to "−1". When receiving a switch message **60***d* from the transmission apparatus **100***d*, the transmission apparatus **100***e* updates the link **300***c* to "−1", and determines presence or absence of loopback of the wavelength λ_1 to λ_3 terminated by the transmission apparatus **100***e*. Since the link **300***e* in the ring information table **120** of the transmission apparatus **100***e* in FIG. **13**B is "−1", loopback is set.

Before transmission of a switch message **60***e*, the transmission apparatus **100***e* set loopback of the wavelength λ_3 by referring to the ring information table **120** of the transmission apparatus **100***b* in FIG. **13**B on presence or absence of switching in the transmission direction.

The ring information tables **120** in FIGS. **13**A and **13**B are partially different from each other. However, the tables in the transmission apparatuses **100***b* and **100***e* each are searched between the link **300***a* and the link **300***c*, and between the link **300***c* and the link **300***e*, causing no problem.

As described above, the protection method described in Embodiment 2 can be applied to triple failures, that is, multiple failures.

Therefore, at multiple failures, it is possible for each transmission apparatus to accurately perform protection processing for each wavelength.

Embodiment 4

In Embodiment 2 or 3, the states of the link **300** and the transmission apparatus **100** are stored in the table to set presence or absence of switching at multiple failures.

In Embodiment 4, information on the link **300** is not stored in the table, and presence or absence of switching is determined on reception of the switch message **50** based on the failure detected by its own node and failure information in the switch message **50**.

For example, in the ring network **10***b* with double failures as illustrated in FIGS. **10**A and **10**B, each transmission apparatus **100** has a ring information table **120***a* illustrated in FIG. **14**. The ring information table **120***a* indicates wavelengths terminated by each transmission apparatus **100**.

Switching performed by the transmission apparatus **100***d* at this time is described. When receiving a switch message **50***c* from the transmission apparatus **100***a*, the transmission apparatus **100***d* determines whether or not other transmission apparatuses **100** terminate each wavelength to the transmission line with failure, based on failure information on the link **300***c* detected by its own node, and failure information on the link **300***a* indicated by the switch message.

The transmission apparatus **100***d* finds that since the link **300***c* is a failure link, all wavelengths are not terminated by the other transmission apparatuses **100** before the failure.

Therefore, the transmission apparatus **100***d* performs switching of the direction toward the transmission apparatus **100***c*.

In consideration of the case where there are no wavelength to be terminated except for itself, like the wavelength λ_2 in the transmission apparatus **100***b*, proper support can be achieved by determining presence or absence of switching in the reception direction as well, at reception of the switch message. Therefore, only information on the transmission apparatus **100**, correct switching as illustrated in FIG. **10**B is enabled.

As described above, Embodiment 4 enables correct switching using the switch message and information on the link **300** with the failure.

Although the preferred embodiments of the ring network has been described, the present invention is not limited to the embodiments, and it should be understood that various changes and alternations could be made by those skilled in the art based on the subject matter of the invention that recited in CLAIMS and disclosed Embodiments of the Invention, and such changes and alternations fall within the scope of the invention.

All examples and conditional language recited herein are intended for pedagogical purposes to aid the reader in understanding the invention and the concepts contributed by the inventor to furthering the art, and are to be construed as being without limitation to such specifically recited examples and conditions, nor does the organization of such examples in the specification relate to a showing of the superiority and inferiority of the invention. Although the embodiments of the present invention have been described in detail, it should be understood that the various changes, substitutions, and alterations could be made hereto without departing from the spirit and scope of the invention.

What is claimed is:

1. A transmission apparatus being one of a plurality of transmission apparatuses included in a ring network, the transmission apparatus comprising:

at least one memory storing wavelength termination information;

at least one demultiplexer;

at least one multiplexer;

a switch, which includes at least one optical-electrical (O/E) converter that performs O/E conversion and at least one electrical-optical (E/O) converter that performs E/O conversion, configured to:

transmit, by the at least one E/O converter to the at least one multiplexer, each of a first plurality of optical signals received, by the at least one demultiplexer to the at least one O/E converter, from a first transmission apparatus to a second transmission apparatus, each of the first plurality of optical signals having each of a plurality of wavelengths, the first transmission apparatus and the second transmission apparatus being included in the plurality of transmission apparatuses, the first transmission apparatus being one adjacent transmission apparatuses of the transmission apparatus in the ring network, the second transmission apparatus being another adjacent transmission apparatuses of the transmission apparatus in the ring network; and

a processor, coupled to the at least one memory, configured to:

receive, by the at least one demultiplexer to the at least one O/E converter, a message from the first transmission apparatus, the message being for setting loopback for at least one wavelength in the ring network, the message being transmitted when a failure of at least one optical signal having the at least one wavelength is detected in a link of the ring network, the at least one wavelength being included in the plurality of wavelengths; and set a loopback to the switch based on the message and the wavelength termination information, the loopback being set for a wavelength of the at least one wavelength

when an optical signal having the wavelength is terminated by the switch and converted to an electrical signal by the at least one O/E converter and

when the optical signal having the wavelength is not terminated and not converted to an electrical signal by any of transmission apparatuses among the plurality of transmission apparatuses from the second transmission apparatus to a transmission apparatus before the link in which the failure is detected,

wherein after the loopback is set for the wavelength, when receiving, by the at least one demultiplexer to the at least one O/E converter, an optical signal having the wavelength from the first transmission apparatus, the switch is configured to

switch, by the at least one E/O converter, the wavelength of the received optical signal from the wavelength to a different wavelength and

transmit, by the at least one E/O converter to the at least one multiplexer, an optical signal, corresponding to the received optical signal, having the different wavelength to the first transmission apparatus.

2. The transmission apparatus according to claim **1**, wherein

the loopback is not set for another wavelength of the at least one wavelength

when an optical signal having the another wavelength is not terminated by the switch and converted to an electrical signal by the at least one O/E converter or

when the optical signal having the another wavelength is terminated and converted to an electrical signal by at least one transmission apparatus among the plurality of transmission apparatuses from the second transmission apparatus to the transmission apparatus before the link in which the failure is detected.

3. The transmission apparatus according to claim **1**, wherein

the switch is further configured to transmit, by the at least one E/O converter to the at least one multiplexer, each of a second plurality optical signals received, by the at least one demultiplexer to the at least one O/E converter, from the second transmission apparatus to the first transmission apparatus, each of the second plurality optical signals having each of the plurality of wavelengths.

4. The transmission apparatus according to claim **1**, wherein

the processor is further configured to:

transmit, by the at least one E/O converter to the at least one multiplexer, the message to the second transmission apparatus when detecting a failure in a link between the transmission apparatus and the first transmission apparatus, and

transmit, by the at least one E/O converter to the at least one multiplexer, the message to the first transmission apparatus when detecting a failure in a link between the transmission apparatus and the second transmission apparatus.

5. The transmission apparatus according to claim **1**, wherein

the message is included in automatic protection switching (APS) signal.

6. The transmission apparatus according to claim **1**, wherein

the message is a message for group protection so that the at least one wavelength is group.

7. A network control method performed in one of a plurality of transmission apparatuses included in a ring network, the one of the plurality of transmission apparatuses has at least one memory storing wavelength termination information, at least one demultiplexer, at least one multiplexer, a switch, which includes at least one optical-electrical (O/E) converter that performs O/E conversion and at least one electrical-optical (E/O) converter that performs E/O conversion, and a processor which is coupled to the at least one memory, the network control method comprising:

transmitting, by the at least one E/O converter to the at least one multiplexer, each of a first plurality of optical signals received, by the at least one demultiplexer to the at least one O/E converter, from a first transmission apparatus to a second transmission apparatus, each of the first plurality of optical signals having each of a plurality of wavelengths, the first transmission apparatus and the second transmission apparatus being included in the plurality of transmission apparatuses, the first transmission apparatus being one adjacent transmission apparatuses of the transmission apparatus in the ring network, the second transmission apparatus being another adjacent transmission apparatuses of the transmission apparatus in the ring network; and

by the processor:

receiving, by the at least one demultiplexer to the at least one O/E converter, a message from the first transmission apparatus, the message being for setting loopback for at least one wavelength in the ring network, the message being transmitted when a failure of at least one optical signal having the at least one wavelength is detected in a link of the ring network, the at least one wavelength being included in the plurality of wavelengths;

setting a loopback to the switch based on the message and the wavelength termination information, the loopback being set for a wavelength of the at least one wavelength

when an optical signal having the wavelength is terminated by the switch and converted to an electrical signal by the at least one 0/E converter and

when the optical signal having the wavelength is not terminated and not converted to an electrical signal by any of transmission apparatuses among the plurality of transmission apparatuses from the second transmission apparatus to a transmission apparatus before the link in which the failure is detected; and

after the loopback is set for the wavelength, when receiving, by the at least one demultiplexer to the at least one O/E converter, an optical signal having the wavelength from the first transmission apparatus,

switching, by the at least one E/O converter, the wavelength of the received optical signal from the wavelength to a different wavelength and

transmitting, by the at least one E/O converter to the at least one multiplexer, an optical signal, corresponding to the received optical signal, having the different wavelength to the first transmission apparatus.

8. The network control method according to claim **7**, wherein the loopback is not set for another wavelength of the at least one wavelength

when an optical signal having the another wavelength is not terminated by the switch and converted to an electrical signal by the at least one O/E converter or

when the optical signal having the another wavelength is terminated and converted to an electrical signal by at least one transmission apparatus among the plurality of transmission apparatuses from the second transmission apparatus to the transmission apparatus before the link in which the failure is detected.

9. The network control method according to claim **7**, further comprising:

transmitting, by the at least one E/O converter to the at least one multiplexer, each of a second plurality optical signals received, by the at least one demultiplexer to the at least one O/E converter, from the second transmission apparatus to the first transmission apparatus, each of the second plurality optical signals having each of the plurality of wavelengths.

10. The network control method according to claim **7**, further comprising:

transmitting, by the at least one E/O converter to the at least one multiplexer, the message to the second transmission apparatus when detecting a failure in a link between the transmission apparatus and the first transmission apparatus; and

transmitting, by the at least one E/O converter to the at least one multiplexer, the message to the first transmission apparatus when detecting a failure in a link between the transmission apparatus and the second transmission apparatus.

11. The network control method according to claim **7**, wherein

the message is included in automatic protection switching (APS) signal.

12. The network control method according to claim **7**, wherein

the message is a message for group protection so that the at least one wavelength is group.

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